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(54) **Halftone dot patterns.**

(57) The dot patterns which may be used to reduce dot gain and moiré effects in halftone images involve printing areas which have inwardly curved edges and variable elongation. Colored images having screens which use these patterns may be printed with the screens at 45° relative angular separations. Alternatively the dot patterns may be regarded as reversed variable oval patterns with varying elongation of the generally oval shaped non-printing areas.

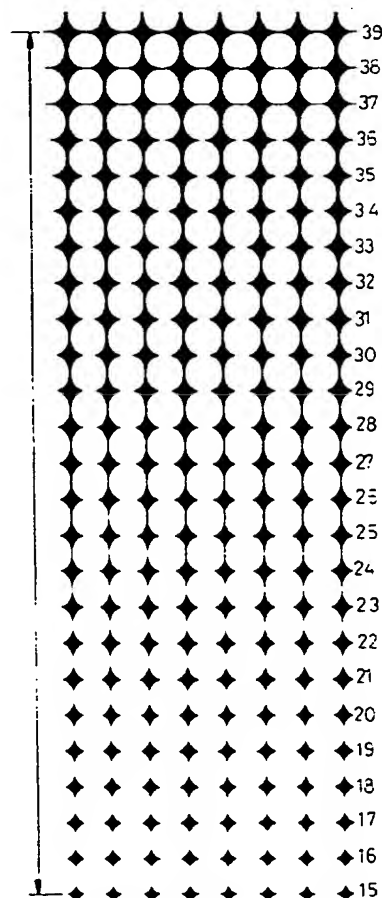


FIG 4b

EP 0 527 655 A2

This invention relates to printing processes and in particular to dot patterns used when preparing halftone images. These patterns include shapes which reduce the perceptibility of certain moiré effects and various tone jumps which are often seen.

In most printing processes it is only possible to apply a single tone of each available ink colour to the print media. Tone variation is then achieved by breaking up each image into fine dots of varying size on a lattice or screen grid. Colour variation is normally achieved by superimposing screens of the primary colours cyan, magenta and yellow, plus black for definition. Ideally human vision integrates the dots over a well prepared image into an accurate impression of the original scene. A final image will almost always include a number of compromises between practical limitations and defects in the printing process, and what can actually be perceived by the human eye and brain.

Round dots at 45° to vertical are least perceptible for a given lattice spacing or screen ruling, and single color images are conventionally printed in this manner. Other dot shapes or combinations of shapes such as square and "elliptical" (diamond shape) are sometimes used, but all have generally straight or outwardly curved edges around the full length of their perimeters. The dots are usually placed on a square lattice having rows spaced at between about 30/cm for newsprint and about 60/cm for higher quality images. Rectangular or other lattices having lower symmetry are also sometimes used. In light tones the dots remain distinct on a light background provided by the print medium, but merge in darker tones which then appear as light dots on a dark background. The printed and non-printed areas of an image therefore appear to reverse from dots to background and background to dots respectively as tone darkens.

When printing colour images undesirable moiré effects in the form of large and small scale patterns are often seen due to periodic alignment of the dots as a whole and of their edges. The large scale patterns are typically bands which intersect to form squares on the order of tens or more dots along each side. This effect is largely removed by suitable relative rotation of the colour screens such as by cyan 15°, magenta 45°, yellow 90° and black 75° anticlockwise from horizontal. Complex mathematical procedures are often used to establish suitable angles. Placing the screens without relative rotation or offset can cause colour shifts in an image where colours of differing opacity, particularly black and yellow, overlap consistently over a large region. Subtle colour shifts may occur in any case due to mis-registration of the screens during their superposition. The small scale patterns of moiré effects are typically rosettes on the order of a few dots width, which cause perceptible speckling of otherwise uniformly coloured areas. This effect has proved more difficult to remove.

A further problem often arises in printing halftone images, known as dot gain, amid tones where adjacent dots are so sufficiently large as to become linked by imprecision in their reproduction. For example in lithography, which includes offset printing, a greasy ink is confined to printing areas of an image plate by dampening the surrounding non-printing areas with water. Unfortunately surface tension at the ink/water interfaces can cause or enhance bridging between closely spaced printing areas creating sudden tone jumps. Ink absorption on poor quality print paper can also lead to bridging. Round and square dots on a square lattice naturally meet their nearest neighbours at 78% and 50% printing area densities respectively. Dot gain causes bridging at slightly lower densities and enhances bridging at slightly higher densities creating discontinuities in regions of an intended smoothly varying tone. This effect is also difficult to remove completely.

Preparation of halftone images is largely carried out using computer controlled devices such as scanners and image setters. A photograph or other artwork to be reproduced is scanned and the original scene is stored in electronic memory or output directly. The images can be manipulated and/or combined with text before a printing medium such as a film or plate is produced. It is normally only in the final output stages that an image is converted to halftone dot screens. The manipulations are complex software operations which may be varied to suit particular images. Similar software is used in other electronic printing and image setting processes such as desktop publishing. Precise control of the dot patterns is necessary in preparing acceptable images, and the computations required for high quality images are often extensive and time consuming. For example, software methods for reducing moiré effects are disclosed in US 4,084,183, (congruent screens), US 4,894,726 (quasi periodic screens), EP 370271 (elongated conventional dots), WO 90/10991 (rectilinear screen transposition) and WO 90/86034 (pseudo random variation of dot shapes). Some images are still prepared using conventional photomechanical equipment such as contact screens. Good summaries of known dot patterns, their various problems and moiré effects are to be found in Colour Screening Technology; A Tutorial on the Basic Issues, The Seybold Report on Desktop Publishing, Vol 6, No. 2, October 1991, Seybold Publications Inc., PA, USA, and Desktop to Press, Issue 9, February 1992, Peter Fink Communications Inc., CA, USA.

It is object of the present invention to provide an alternative dot pattern which can be used to reduce rosette moiré, dot gain and tone jump effects in halftone images.

A halftone image having a dot pattern according to the invention is created by printing dots having inwardly curved edges. In light tones the dots may re-

semble pin cushions having pronounced cusps. In dark tones the dots are effectively merged to create non-printing dots which may be oval shaped. As tone varies from light to dark, the pin cushions are increasingly elongated along one direction and meet their nearest neighbours in two distinct stages, first in the direction of elongation and then in a direction substantially perpendicular to it. The dot screen is typically formed from a square lattice so there are typically four nearest neighbours symmetrically placed at equal distances. As tone continues to darken after the dots have joined, the elongation is gradually decreased so that the oval shaped non-printing dots approach round dots. The pattern may also be considered overall as a reversed elliptical dot pattern in which the ellipses vary from round to a maximum ellipticity and back to round across the full range of tones. When a number of screens are superimposed the inwardly curved edges of the printing areas do not align so readily to form perceptible rosettes as do conventional dots. Further, the elongation may be varied so that dot gain occurs in tones where its perceptibility also is minimised.

At the present time as this specification is prepared, the optimum uses and ramifications of the invention have not been fully explored. In preparing colored images it has been found that the primary color and black screens are best placed at 45° separations from each other. For example cyan 45°, magenta 135°, yellow 90° and black 0°. Screens which are separated by 90° may generally be regarded alternatively as being at 0° so that in this example there are essentially only two angles for compilation of dot patterns, 0° and 45°. This represents a considerable computational simplification over conventional screen angles.

The cyan and magenta screens will normally have a deliberate offset or mis-registration from each other to avoid possible color shifts. Yellow and black screens may also be offset from each other, and may be printed with little or no elongation of the dots. The yellow and/or black lattice spacings may also be increased and/or decreased relative to cyan and magenta. Final determination of these possibilities awaits full software implementation of the invention and will depend on particular images.

Examples of the invention will be described with reference to the drawings of which:

Figures 1a, 1b and 1c show coarse conventional round, square and elliptical dot patterns respectively, varying uniformly between light and dark tones;

Figure 2 is an illuminated globe image using a conventional variable round dot pattern;

Figure 3 shows reversal of a coarse conventional round dot pattern to produce printing areas having inwardly curved edges;

Figure 4a and 4b show reversal of a variable oval

dot pattern in which the dots vary from round to oval and back to round according to the invention; Figures 5a, 5b and 5c show example variable oval dot outlines superimposed upon common centres according to the invention;

Figures 6a and 6b show respectively two conventional round dot screens overlapping at 30° and two reversed dot screens according to the invention overlapping at 90°;

Figures 7a and 7i show example dot patterns for various screen combinations according to the invention;

Figures 8a to 8i show corresponding conventional round dot patterns for contrast with figures 7a to 7i; and

Figure 9 is a flowchart indicating a general process in which the invention may be implemented.

Referring to these figures it will be seen that the dot patterns are magnified about 10 to 100 times in black and white for purposes of their description. The visual effects resulting from integration by the human eye over a halftone image at normal scales are not evident but should be appreciated by a skilled reader. Particularly the improvements to be obtained in colour images by inwards curvature of printing dot edges in light to middle tones and to be obtained in single color images by dot elongation will be appreciated.

The various forms of computer hardware and software used to implement dot patterns according to the invention will also be known to the skilled reader, or at least will be available for consideration through the references given above. For example, a range of desktop publishing and high end scanner equipment and software is available through suppliers such as Adobe, Agfa, Crosfield, Linotype-Heil and Scitex. As new patterns are developed the hardware and/or software may be correspondingly upgraded. A typical process of preparing a halftone image, particularly a colored image as implemented on their equipment, is outlined in the flowchart of figure 9.

In general terms, a scene is electronically scanned from a film or other artwork to be printed, and the data obtained is stored as pixel based color and intensity information. The pixels are generally aligned with the vertical and horizontal directions of movement of the scanner. The data is then processed into a standardised format such as known under the trade mark POSTSCRIPT and from there into up to four halftone screens which represent the primary colors and black as required. These screens are created from the pixel information by various raster image processor programs which calculate the dot shapes, lattice spacings and screen rotation angles. An operator normally has a range of dot patterns available through software installed on the equipment. The operator selects appropriate shapes, spacings and angles in reaching an acceptable image during proofing. In traditional printing operations each screen is then output individ-

ually, to create up to four films or plates which are used to print multiple copies of the final black and white or colored image. This part of the process is known as image setting in the case of desktop publishing and as scanner output in the case of "high end" systems. In other operations such as ink jet printing it is possible to output a colored image directly.

Figures 1a, 1b and 1c show conventional round, square and "elliptical" dot patterns respectively on square lattices, varying smoothly in size from about 10% print area density in light tones to about 90% area density in dark tones. Round dots have outwardly curved edges by definition whereas square or diamond shaped dots have flat edges between four points. The square patterns are invertible in that the printed areas in light tones have similar shapes to the non-printed areas in dark tones and vice versa.

Figure 2 demonstrates a more complicated dot pattern in which conventional round dots in light tones become square dots in middle tones with reversal of the round dots in dark tones. This is often referred to as the Euclidean dot pattern. The edge curvature of printed areas correspondingly changes from outward to flat to inward respectively. Moiré effects do not arise in Figures 1 and 2 as only a single screen is present in each case. Dot gain is not apparent due to the magnification.

Figure 3 shows a reversed round dot pattern varying uniformly from light to dark tones. The dots in light tones have inwardly curved edges between cusps distributed on two planes of mirror symmetry. Their points could perhaps be flattened or rounded as desired. Each dot meets its four nearest neighbours simultaneously at around 22% area density. Otherwise the inwards curvature extends along substantially the full length of all printed areas. The non-printed areas have corresponding outwardly curved edges and separate to appear as round dots in the dark tones. Overall the pattern is seen to be effectively a reversal or negative of the conventional round dot pattern in Figure 1a throughout the entire range of tones, and in this respect may be considered a pattern of light round dots on a dark printed background. By virtue of this reversal all print area edges are circles or circular arcs but could be other smooth curves as desired, or as required to link with the end points. Also the dots need not be fourfold symmetrical or printed on a square lattice as shown. Rosette moiré effects in coloured images can be reduced by printing dot patterns having inwardly curved edges as will be evident from later figures in which two lattices are superimposed. Tone jumps due to dot gain remain a problem however, as with the conventional round dot pattern.

Figures 4a and 4b show a reversed variable oval dot pattern according to the invention. In this form the generally pin cushion shaped dots are elongated along a plane of mirror symmetry in light quarter to middle tones, so that nearest neighbours meet first

vertically along the direction of tone darkening and then second horizontally in the corresponding perpendicular direction. Each dot meets two opposing pairs in two distinct stages of around 22% and 36% area density. This pattern is seen to be effectively a reversal or negative of a round dot pattern in which the dots become oval in middle tones. Figures 4a shows a full range of tone from 0% to 100% while Figure 4b shows more detail of the fourfold/twofold or alternately the round/oval variation from about 15% to 39% area density. Rosette moiré effects can be reduced as with the pattern of Figure 3, but now by controlling dot elongation the perceptibility of any tone jumps can also be reduced by splitting dot gain into two less obvious stages which in turn may be shifted among a range of tones.

Figures 5a, 5b and 5c show example variations of dot edges according to the invention superimposed on common centres. The diagonally lined squares facilitate comparison and measurement in production. The edges are not necessarily mathematical ellipses but may take any suitable oval or approximately similar form as can be generated by computer. Figure 5a shows the gentle round-oval-round variation of Figures 4a and 4b. Figures 5b and 5c show more severe distortions resulting in greater separation of the dot gain stages.

Figures 6a and 6b are an illustration of the reduction in rosette moiré effect which can be achieved according to the present invention. Figure 6a shows rosettes created by superimposing two conventional round dot screens at 30°, as is common with cyan and magenta in coloured images. Figure 6b shows a smoother variation of similar tones created by superimposing two reversed variable oval dot screens at 90° according to the invention. Preparing colored images using all four possible is less straightforward.

It has been found that the primary color screens are apparently best placed at 45° angular separations, such as cyan 45°, magenta 135° and yellow 90°, with black placed at 0° or 90°. Further, that not every screen need be printed according to the invention. For example, at least cyan and magenta should use elongated dots of the reversed variable oval dot pattern, while yellow may use only the reversed round dot pattern. Black may only need the reversed round dot pattern, or may even give satisfactory images using the conventional round dot pattern itself.

It has also been found that black dots are often not necessary in preparing a well defined colored image. For example, the primary color screens may be used alone at the angle and with the patterns mentioned above.

It is also generally required that the cyan and magenta screens should be offset from each other to avoid possible color shifts. When the screens are formed from square lattices the offset should be about half a lattice spacing parallel with either of the

lattice directions, for best results in view of the accidental offsets which often occur during printing. Yellow and black screens should also sometimes be offset to avoid shifts. The nature of these offsets has yet to be fully explored but will be evident to a skilled reader working on a particular image.

In some images the possibility of color shifts and moiré effects has been reduced with the 45° angles and reversed patterns mentioned above, by decreasing the black lattice spacing by a factor of about cosine 45° (about 0.71) relative to the cyan and magenta spacing. In a smaller number of cases the yellow lattice spacing has been correspondingly increased by this factor. Again the nature of these adjustments to the spacings has yet to be fully explored, but will be evident to a skilled reader working on particular images.

Figures 7a to 7i show the dot patterns of a test which has been carried out to date according to the invention. Figures 7a to 7d represent individual screens of cyan 135°, magenta 45°, yellow 0° and black 0/90°, all at tone values where the printing and non-printing areas have linked with two or four of their nearest neighbours. Cyan and magenta use the reversed variable oval dot pattern. Yellow and black use simply the reversed round dot pattern. The black lattice spacing has been reduced by a factor of about 0.71 relative to the others. Figures 7e to 7g show screens superimposed in pairs, namely cyan/yellow, magenta/yellow and cyan/magenta. In figures 7f and 7g the cyan and magenta have been offset by half a lattice spacing parallel to their lattice directions, which are diagonal on the page as shown. The visible effect is somewhat unrealistic in that yellow normally has substantially less impact on the eye than the darker colors but here all colors must be shown equally in black. Figure 7h shows the cyan, magenta and yellow screens superimposed. A very slight moiré effect is apparent primarily because the colors must be shown in black as mentioned. Figure 7i shows the black screen of figure 7d superimposed on figure 7h. Again there is a slight moiré effect due to the overall black color representation whereas under normal printing circumstances the colors would have different impacts and the final image screen would be virtually moiré free.

Figures 8a to 8i show an attempt to contrast with figures 7a to 7i, the conventional round dot patterns which would typically have been used. Figures 8a to 8d represent individual screens of cyan 15°, magenta 45°, yellow 0° and black 75°. Figures 8e to 8g show these screens superimposed in pairs, namely cyan/yellow, magenta/yellow and cyan/magenta. Figure 8h shows the cyan, magenta and yellow screens superimposed. Figure 8i shows the black screen of figure 8d superimposed on figure 8h. Both large and small scale moiré effects can be seen in these figures, although the effects are not so apparent as they

normally would be in a complete colored image at normal lattice spacings of screen rulings. The effects of dot gain are not at all apparent due to the artificial manner in which these figures must be presented.

## Claims

1. A method of preparing a halftone image wherein tone variation in light tones is produced by creating printing dots which have inwardly curved edges and which are increasingly elongated with darkening tone.
2. A method according to claim 1 wherein the dots are elongated substantially in the direction of darkening tone.
3. A method according to any preceding claim wherein the edges of the dots are portions of ellipses.
4. A method according to any preceding claim wherein the dots are elongated along a plane of substantially mirror symmetry.
5. A method according to any preceding claim wherein the dots have just two planes of substantially mirror symmetry.
6. A method according to any preceding claim wherein the dots join with their nearest neighbours in two distinct stages as tone darkens.
7. A method according to any preceding claim wherein the edges of the dots are substantially smooth curves which meet to form cusps.
8. A method according to any preceding claim wherein the dots are substantially pin cushion shapes.
9. A method of preparing a halftone image wherein tone variation in dark tones is produced by creating non-printing dots which have outwardly curved edges and which are increasingly elongated with lightening tone.
10. A method according to claim 9 wherein the dots are elongated substantially in the direction of lightening tone.
11. A method according to claim 9 or 10 wherein the dots are substantially ellipses.
12. A method according to any one of claims 9 to 11 wherein the dots are elongated along a plane of substantially mirror symmetry.

13. A method according to any one of claims 9 to 12 wherein the dots have just two planes of substantially mirror symmetry.
14. A method according to any of claims 9 to 13 wherein the dots join with their nearest neighbours in two distinct stages as tone lightens.
15. A method according to any one of claims 9 to 14 wherein the edges of the dots are substantially smooth curves.
16. A method of printing a coloured halftone image wherein tone variation from light to dark in at least cyan and magenta screens is produced by creating printing areas which have inwardly curved edges, and wherein each primary colour screen is placed at an angle which is substantially a multiple of 45° to any other primary colour screen.
17. A method according to claim 16 wherein the cyan and magenta printing areas in light tones are dots which become increasingly elongated as tone of those colors darkens.
18. A method according to claim 16 or 17 wherein the cyan and magenta non-printing areas in dark tones are dots which become increasingly elongated as tone of those colors lightens.
19. A method according to any one of claims 16 to 18 wherein the cyan and magenta screens are relatively offset.
20. A method according to any of claims 16 to 19 wherein tone variation in all primary colour screens is produced by creating printing areas having inwardly curved edges.
21. A method according to any one of claims 16 to 20 wherein tone variation in a black screen is produced by creating printing areas which have inwardly curved edges.
22. A method according to any one of claims 16 to 21 wherein the cyan and magenta screens are placed at substantially 90° to each other.
23. A method according to any one of claims 16 to 24 wherein yellow and black screens are placed at substantially 90° to each other.
24. A method according to claim 21 wherein the black screen is placed at an angle which is substantially a multiple of 45° to any other screen.
25. A method according to claim 24 wherein the black screen has a lattice spacing which is reduced by a factor of substantially cosine 45° relative to the cyan and magenta screens.
26. A computer algorithm which implements the method of preparing a halftone image according to any preceding claim.
27. Computer controlled apparatus which implements the method of preparing a halftone image according to any preceding claim.
28. A computer controlled apparatus for preparing halftone images comprising:
  - means for scanning a previously recorded scene to produce information representing color and intensity variation in the scene;
  - means for processing the information to create halftone dot screens representing primary colors and/or black tone variation in the scene; and
  - means for printing the halftone screens on an output medium;
  - wherein the means for processing includes means for producing tone variation in the halftone dot screens by creating printing areas which have inwardly curved edges and which vary in elongation between light and dark tones.
29. Apparatus according to claim 28 wherein the printing areas in light tones are dots having an increasing elongation with darkening tone.
30. Apparatus according to claim 28 or 29 wherein the non-printing areas in dark tones are substantially oval shapes having an increasing elongation with lightening tone.
31. A computer controlled apparatus for preparing halftone images comprising:
  - means for receiving information representing color and intensity variation in a previously recorded scene;
  - means for processing the information to create halftone dot screens representing primary colors and/or black tone variation in the scene; and
  - means for printing the halftone screens on an output medium;
  - wherein the means for processing includes means for producing tone variation in the halftone dot screens by creating printing areas which have inwardly curved edges and which vary in elongation between light and dark tones.
32. A halftone image wherein tone variation is produced at least in part by printed areas which have inwardly curved edges and which vary in elongation between light and dark tones.



33. An image according to claim 31 wherein the printed areas in light tones are dots having an increasing elongation with darkening tone.
34. An image according to claim 32 or 33 wherein the non-printed areas in dark tones are substantially oval shapes having an increasing elongation with lightening tone. 5
35. An image according to any one of claims 32 to 34 having primary color screens separated by angles which are substantially multiples of  $45^\circ$ . 10
36. An image according to any one of claims 32 to 35 having a black screen placed at an angle which is substantially a multiple of  $45^\circ$  to any other screen. 15

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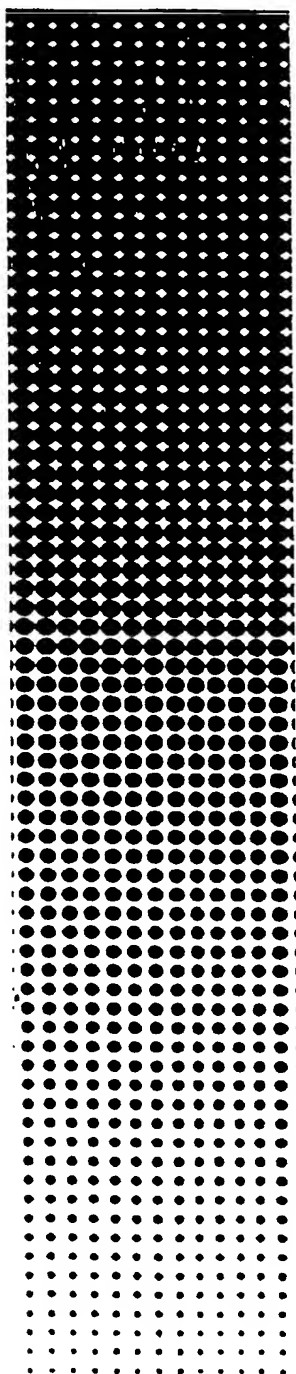


FIG 1a

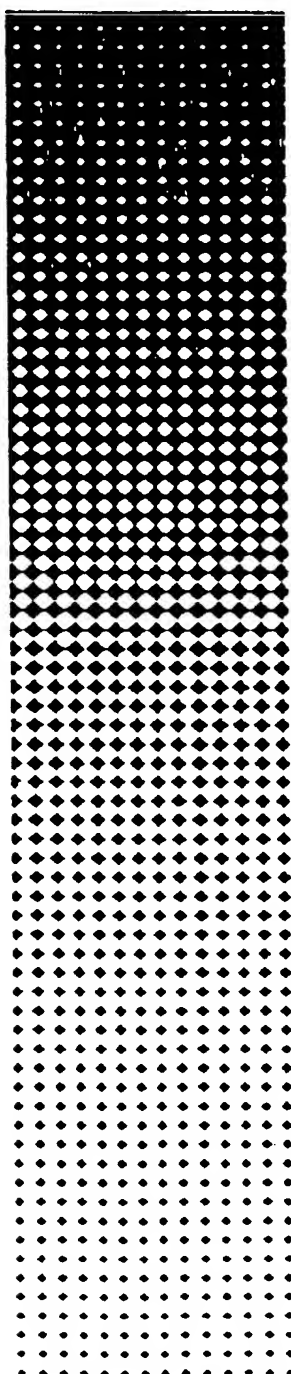


FIG 1b

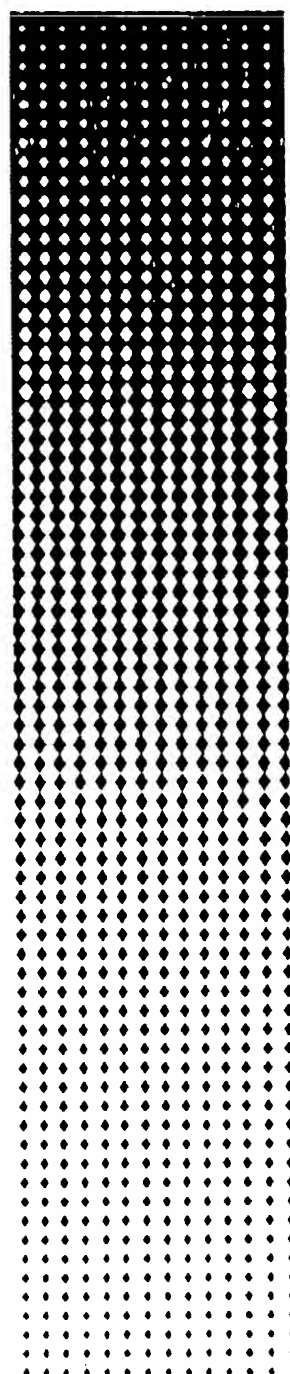


FIG 1c

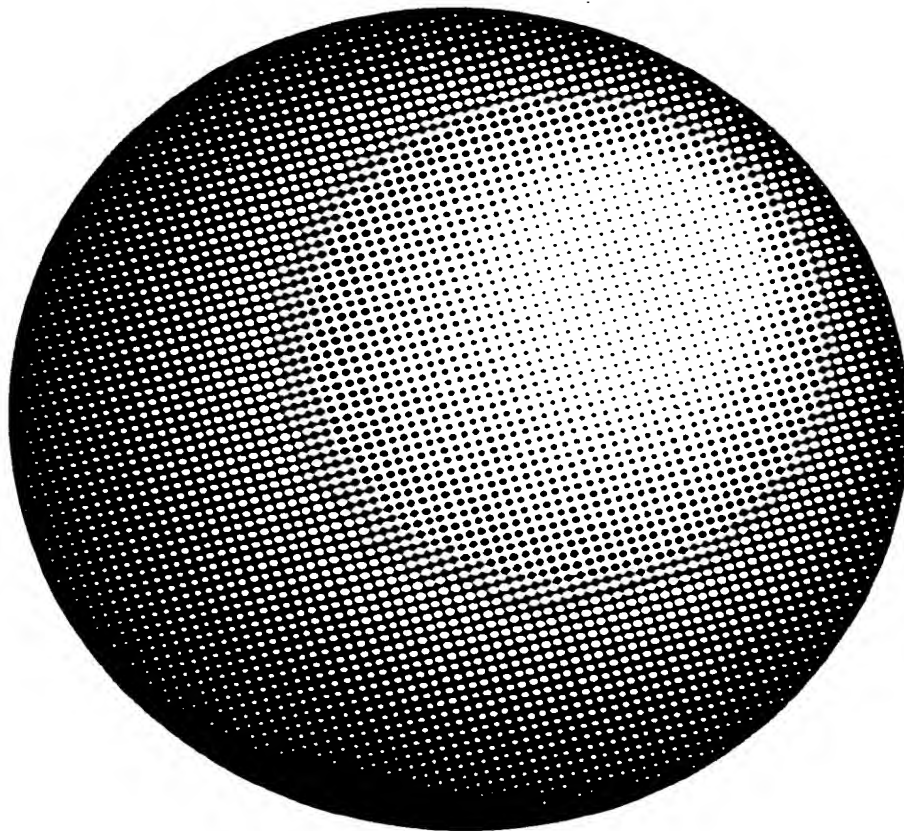


FIG 2

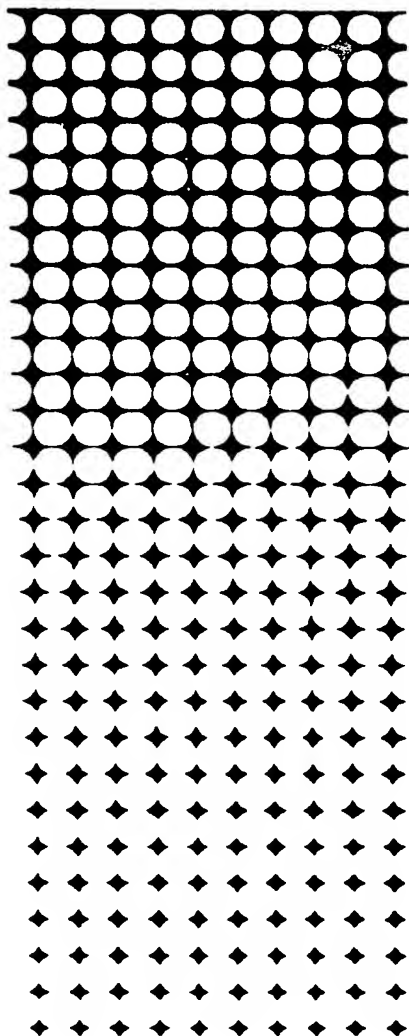


FIG 3

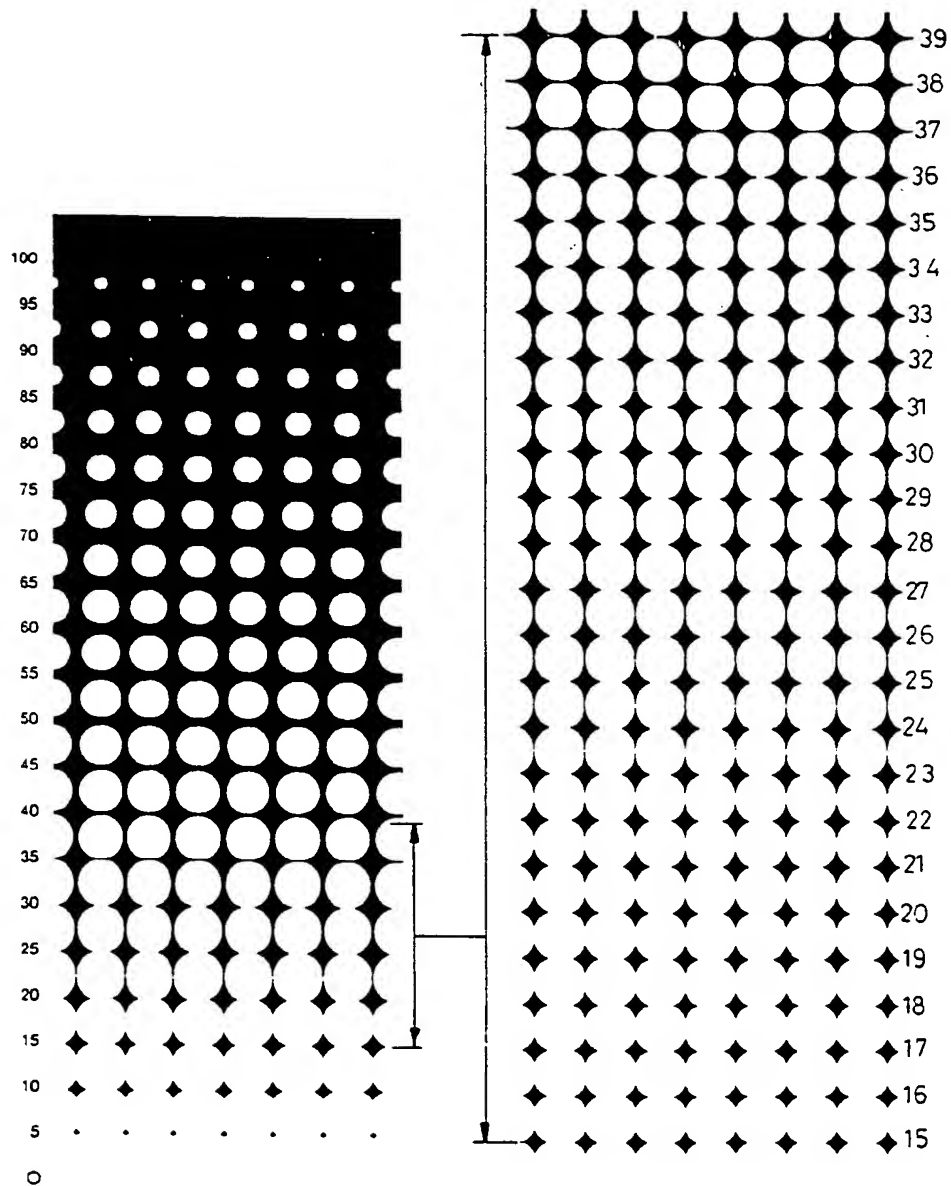


FIG 4a

FIG 4b

FIG 5a

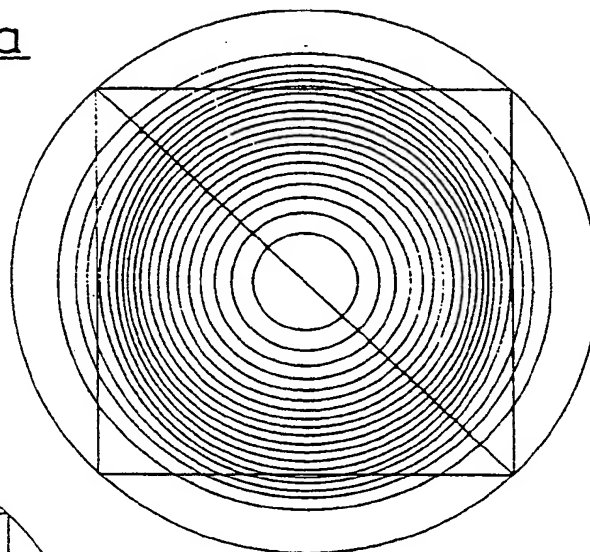


FIG 5b

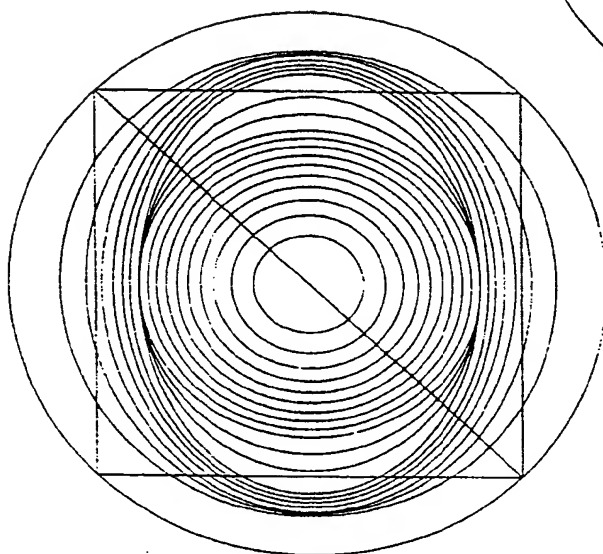
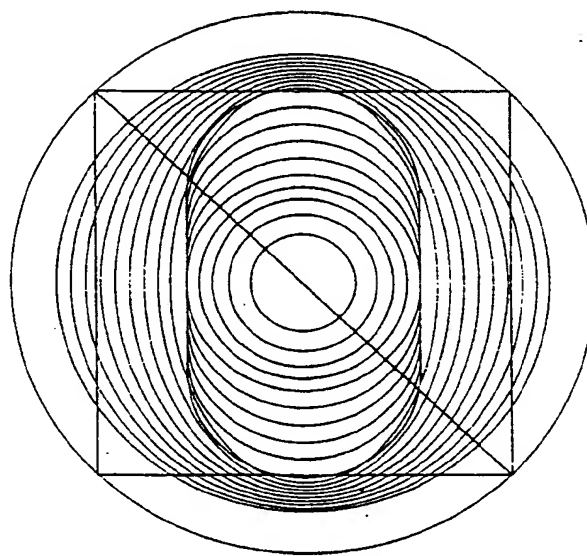


FIG 5c



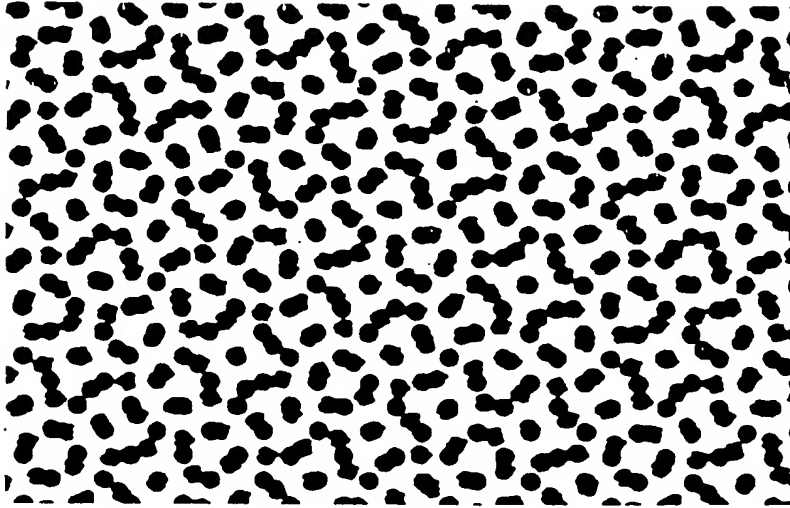


FIG 6a

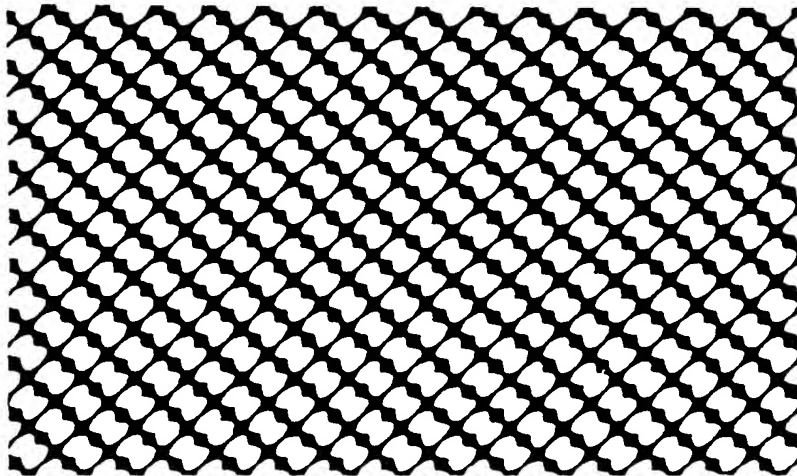


FIG 6b

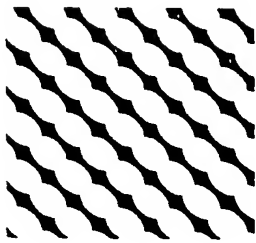


FIG 7a

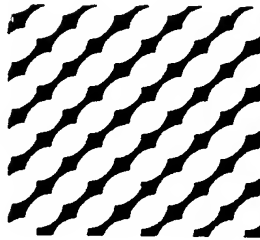


FIG 7b

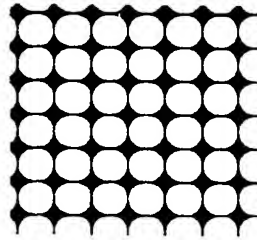


FIG 7c

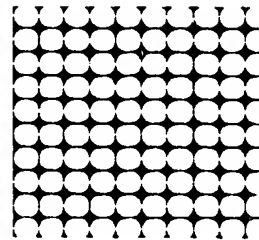


FIG 7d

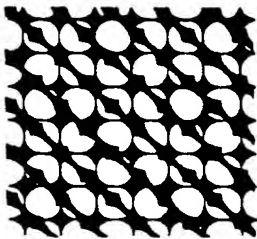


FIG 7e

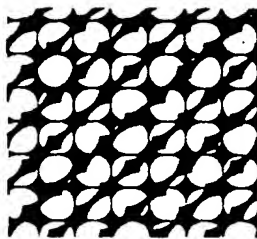


FIG 7f

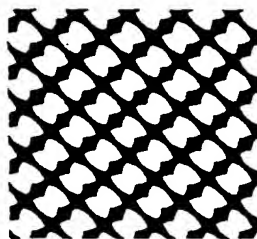


FIG 7g

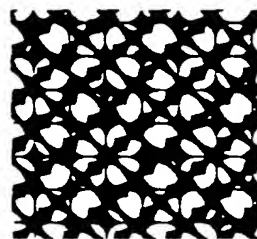


FIG 7h

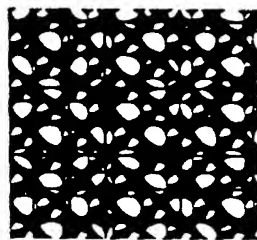


FIG 7i



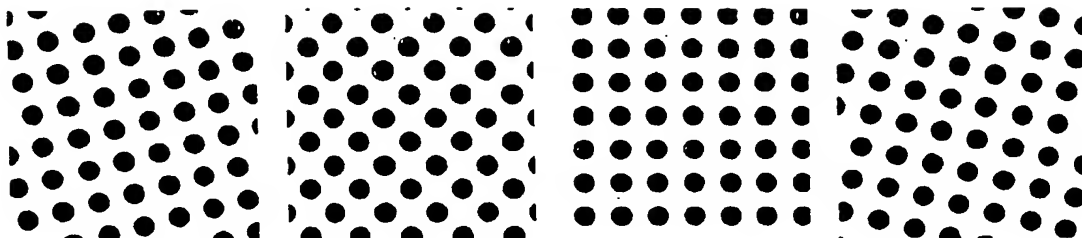


FIG 8a

FIG 8b

FIG 8c

FIG 8d

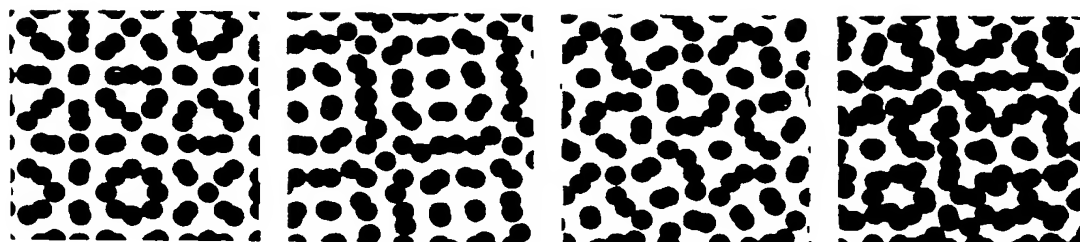


FIG 8e

FIG 8f

FIG 8g

FIG 8h

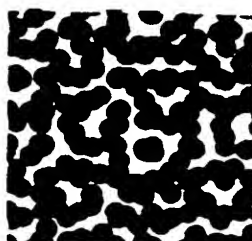
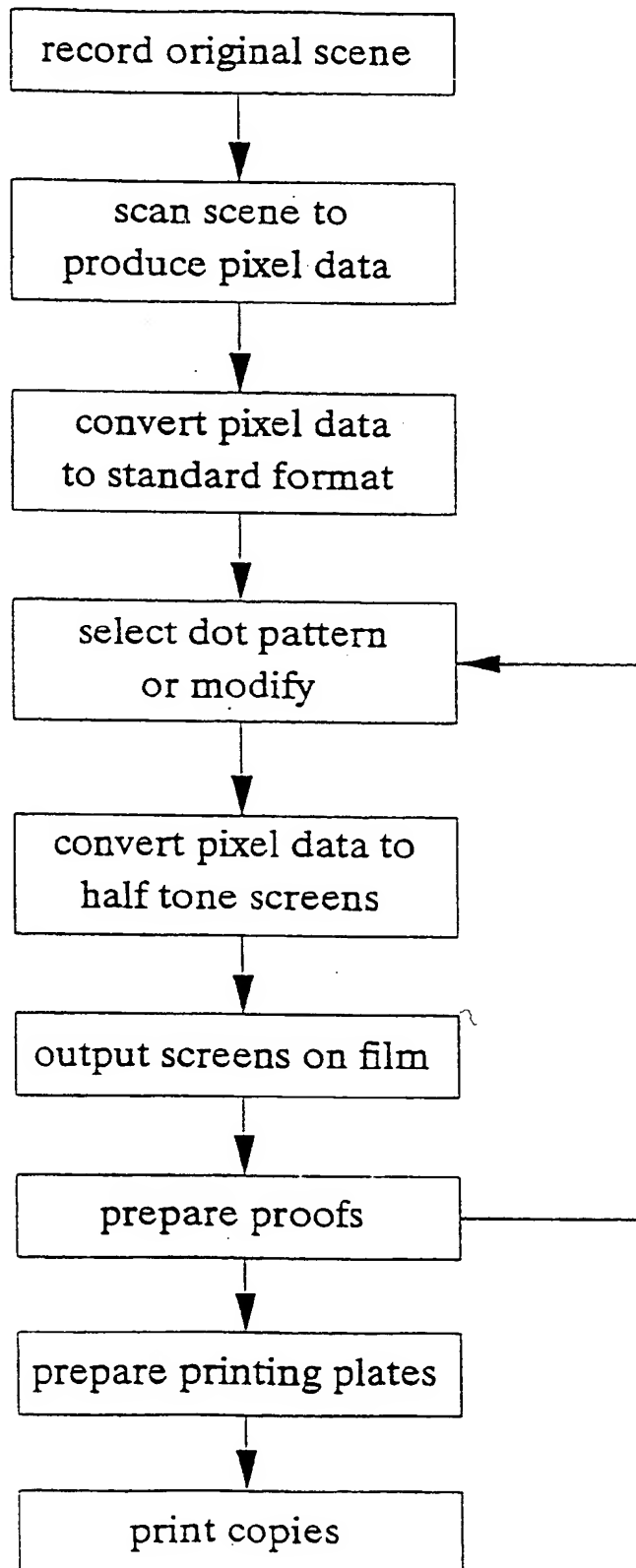


FIG 8i

FIG 9





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(54) **Halftone dot patterns.**

(57) The dot patterns which may be used to reduce dot gain and moiré effects in halftone images involve printing areas which have inwardly curved edges and variable elongation. Colored images having screens which use these patterns may be printed with the screens at 45° relative angular separations. Alternatively the dot patterns may be regarded as reversed variable oval patterns with varying elongation of the generally oval shaped non-printing areas.

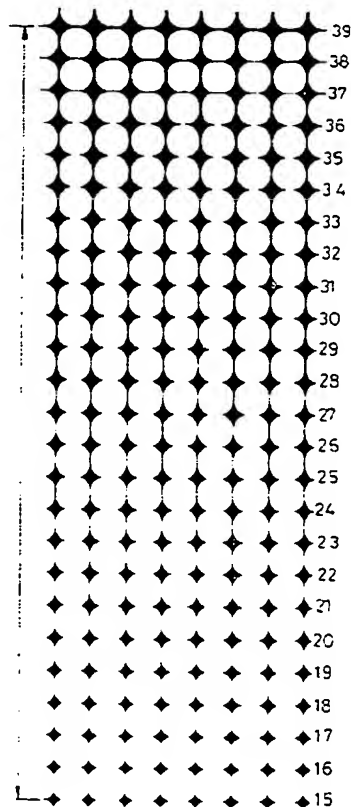


FIG 4b

**EP 0 527 655 A3**



European Patent  
Office

# EUROPEAN SEARCH REPORT

Application Number  
EP 92 30 7424

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.5)
D, A	EP-A-0 370 271 (DAINIPPON SCREEN MFG) 30 May 1990		H04N1/46 H04N1/40 G03F5/00
A	DE-A-29 17 242 (DEUTSCHE FORSCH DRUCK REPROD) 6 November 1980		
A	DE-A-20 25 609 (A.W. JEMSEBY) 3 December 1970		
			TECHNICAL FIELDS SEARCHED (Int.Cl.5)
			H04N G03F
The present search report has been drawn up for all claims			
Place of search		Date of completion of the search	Examiner
THE HAGUE		30 June 1995	Haenisch, U
<b>CATEGORY OF CITED DOCUMENTS</b> X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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